A Proposal to Study Inelastic Interactions of $\pi^{\pm}$ Mesons and Protons with Neon in 30-inch Bubble Chamber .

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Abstract

We propose to study multiparticle production processes in $\pi^{\pm}$ Ne and p Ne interactions at 100 GeV/c in 30-inch bubble chamber filled with the neon-hydrogen mixture.

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We are proposing to study the multiple processes in the interactions of $\pi^{\pm}$-mesons and protons with neon in 30 inch bubble chamber filled with a mixture of Ne and H_2 consisting of about 30 mole % Ne.

During the last years there has been great interest to study multiple hadron-nucleus collisions at high energies. This interest is neither trivial and no limited only with the heuristic consideration of this problem, but also is connected with the hope to obtain some useful information on the dynamics of strong interactions (see, e.g. [1]).

In current time there is a large number of models proposed for the multiparticle production processes on nuclei. For example, these models are the following: the cascade [2,3] and the cluster formation [4-6] models, the energy flux cascade model [7] , the parton [8-10] and the "quark" [11] models. There has appeared a principal new idea of "bare" hadron [12,13] , in accordance with that the hadrons need some time τ_0 in their rest system to restore their fields. In application to hadron--nucleus interactions this idea leads to the picture, which considerably differs from cascading processes. The experimental examination of this idea is very important.

Apart from this there is also some interest to study the production of resonances on nuclei and the definition of the cross section of the resonance-nucleon scattering. The available data, for example, for the cross sections of ρN and A_1N interactions are quoted with the large errors and they don't permit to conclude the equality: $\sigma(\rho N) = \sigma(A_1 N) = \sigma(\pi N)$. Using the nucleus as a target one can study also the pure nuclear effects, such as : the fragmentation into slow protons; the scaling phenomena in the processes with the proton production [14] ; the production of multibaryon resonances and the final state interaction of protons [15] ; the isobar production in nuclei and so on.

The main problems, which we suppose to study in 30 inch bubble chamber with a mixture of Ne and H_2 are the following:

1. The multiplicity and the inclusive production of pions, of slow protons and strange particles in $\pi^{\pm}(p)$Ne collisions at the same energy; the comparison of the obtained experimental results with the data on $\pi^{\pm}p$, pp , $\pi^{\pm}d$ and pd interactions. From this analysis one can obtain the dependence of the inclusive spectra on the atomic number of target.

2. The examination of the factorization hypothesis of the pomeron and the meson exchanges in the target fragmentation region. An information on this can be obtained from the analysis of the inclusive distributions of pions in $\pi^{\pm}$ Ne and p Ne interactions in the target fragmentation region. The examination of the duality criteria in hadron-nucleus collisions, for example, the channels $\pi^{\pm}$ Ne $\rightarrow \pi^{\mp}$ + anything are exotic in the $ab\bar{c}$ - -channel ~~and~~, there must be observed the early scaling. The comparison of these data with the experiments at 10.5 and 200 GeV/c [16] will be useful from this point of view.

3. The incoherent production of ρ - mesons on neon and the de~~finition~~termination of the cross-section of ρ N-interaction.

4. The study of the scaling effects in the reactions $\pi^{\pm}$ Ne $\rightarrow$ $\rightarrow p_{\text{backward in lab.sys.}}$ + anything and pNe $\rightarrow p_{\text{backward in lab.sys}}$ + ... and the comparison with the available data on the reactions

$\pi^{\pm}(p) + A \rightarrow p_{backward}$ + anything in the range (1 - 40)GeV/c.

5. Search for the multibaryon resonances (2p, 3p, 4p, Λ°p, Σp etc) and study of interactions of protons in final state. To study the abovementioned problems we ~~suppose~~ hope to expose the 30 inch bubble chamber filled with a mixture of Ne (30 mole %) and H_2(70 mole %) by the beams of π^+ and π^- mesons and protons at momenta of 100 GeV/c with the average number of beam particles $\bar{n}_b = 3 - 4$ per picture.

We need about 10000 pictures from the exposition by π^+'s, 10000 pictures from π^-'s and 10000 pictures from protons. We estimate that in these pictures will be recorded not less than 10000 interactions of π^+ mesons and π^- mesons and about 15000 interactions of protons with neon nucleus. ~~The such~~ This statistics is enough to obtain good results. The availablity of the data on π^+Ne and π^-Ne interactions will give the possibility to determine the momentum spectrum of the protons above 1 GeV/c subtracting charged particle momentum spectra obtained from the charge-symmetric π^+Ne and π^-Ne collisions.

There are the data handling system consisting from four semi-authomatic devices and six scanning and measuring tables with good precision in our Laboratory. This system is on-line with the computer. Really we can measure more than 12000 events per year.

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A STUDY OF INELASTIC INTERACTIONS OF $\pi^{\pm}$ MESONS AND PROTONS WITH NEON NUCLEI AT 100 GeV/c

(ADDENDUM TO PROPOSAL #504)

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ABSTRACT

We propose to study the multiple production of particles in $\pi^{\pm}Ne$ and pNe interactions at 100 GeV/c in the 15-foot or in the 30-inch Fermilab bubble chamber filled with a heavy Ne-H_2 mixture (≃ 50% neon atomic).

The aim of this experiment is to study the space-time structure of multiple production using more accurate experimental data. The use of a bubble chamber will give us an advantage of 4π-geometry, a unique target, a good efficiency for detecting neutral particles (γ's and strange particles) and will enable us to measure the momenta of secondaries.

We propose to study the multiplicity and inclusive spectra of charged and neutral pions, strange particles and protons produced in $\pi^{\pm}Ne$ and pNe collisions. Once compared to existing $\pi^{\pm}p$, $\pi^{\pm}d$, pp and pd interactions, these experimental data will give very useful information on the A-dependence of the inelastic characteristics of particles produced in hadron-nucleus interactions. We propose also to study the correlations of pions, especially in the range of large rapidities in order to search for short-range correlations. In addition, we plan to study the inclusive production of ρ-mesons in $\pi^{\pm}Ne$ and pNe interactions. If the 15-foot bubble chamber is used, it will be possible to make calorimetry measurements which are important for current neutrino experiments and also provide useful information for future high energy neutrino experiments in the 15-foot bubble chamber with NeH_2 mixtures such as those which will be available with the energy doubler. We will also be able to compare the properties of hadronic systems produced in hadron-neon and neutrino-neon interactions.

The experiment requires 7000 pictures per beam (π^-, π^+, p) at momentum 100 GeV/c (≃ 21000 pictures in total) with 1-2 beam particles per frame for exposure of the 15-foot bubble chamber or ≃ 10000 pictures per beam (≃ 30000 pictures in total) with 4-5 beam particles per frame for exposure of the 30-inch bubble chamber. This will give us approximately 8000-9000 inelastic events per beam. The proposed experiment will take approximately 60 hours.

I. INTRODUCTION

We are proposing to study the multiple production of particles in $\pi^{\pm}Ne$ and pNe interactions at 100 GeV/c. We would like to take data from an exposure of the 15-foot or the 30-inch Fermilab bubble chamber filled with a heavy mixture of neon and hydrogen ($\approx$ 50% neon atomic).

The aim of this experiment is to study the space-time structure of multiple hadron production on the basis of more accurate experimental data. We will also be able to make the calorimetry measurements in the 15-foot bubble chamber which is necessary for current and future experiments with high energy neutrino beams.

II. MOTIVATION

The great interest which has developed in the last few years in the study of multiple production in hadron-nucleus, hA, interactions at high energies is based on the hope of obtaining useful and very important information on the space-time structure of hadron collisions.

The first studies of hA interactions made with cosmic rays and accelerator beams using emulsion techniques showed[1] the weak dependence of the characteristics of secondary hadrons on the atomic number of the nuclear target. Lately, more accurate experiments confirmed this result.[2,3]

The observed weak A-dependence of inclusive characteristics of the produced particles (multiplicity, angular distributions in the forward direction, inelasticity, etc.) contradicted the expectations of a simple cascade picture of hA collisions[23] and stimulated, in particular, the development of new theoretical concepts.[4-8] For example, almost all current models of hA interactions are based on the main assumption that the development of the observed ("asymptotic") final state in hadron-nucleon interactions needs a long time compared to the typical scale of strong interactions ($\tau \sim m_\pi^{-1} \sim 10^{-23}$ sec). For hA collisions, such a picture leads to a weak A-dependence of the inclusive spectra of particles emitted in the forward direction and suppression of cascading in the nucleus.[6-8] On the other hand, recent parton[8] and multiperipheral models[6,7] predict that cascading should occur only for slow particles (low rapidity range) and this effect is expected to be more pronounced in heavier nuclei. Our recent analysis of π^-Carbon interactions at 40 GeV/c showed[9] that this latter picture agrees with experimental data. The confirmation of this result using heavier nuclei at higher energy is very important ($A_{Ne} \cong 1.7\ A_C$).

Most of the existing experimental data on hA interactions were obtained using emulsion techniques[3], solid targets from electronic experiments[2] and the bubble chambers.[9-14] In emulsion experiments the target is a composition of several nuclei with significantly different atomic numbers. This latter point has made it difficult to study the characteristics of secondary particles on the atomic weight of the nucleus. Moreover, as a rule, in these experiments there is no information on the momentum spectrum of produced particles. At the present time, there are only results from electronic experiments[2] in which only the average multiplicities and angular distributions of secondary fast ($\beta > 0.85$) particles in the limited angular interval ($0 < \theta_{lab} < 110^\circ$) were measured. Moreover, in this experiment it was not possible to obtain information on the slow protons and to separate particles according to their charge.

The experiments in bubble chambers filled with heavy liquid (propane, neon-hydrogen mixture, xenon, etc.) have the advantage of 4π-geometry, a unique target and the possibility of detecting slow ($p \lesssim 1.0$ GeV/c) protons. In addition, the secondaries can be separated according to their charge and there is a good efficiency for detecting neutral particles such as γ-quanta and neutral strange particles.

Unfortunately, there are only few data on hA interactions obtained in bubble chambers at relatively low energies ($E_{lab} \leq 40$ GeV/c)†, where the finite energy corrections for some models of hA interactions are not trivial. In our opinion, the use of bubble chambers with heavy liquids, especially Ne-H_2 mixture, exposed to high energy beams can provide very useful and rich experimental information on hA interactions.

III. PROBLEMS PROPOSED TO STUDY

In the proposed experiments we are planning to study the following characteristics of $\pi^{\pm}$Ne and pNe interactions.

a) The multiplicity of secondaries (including charged and neutral pions, protons and strange particles). Recently, in the two-channel model by Shabelsky[15] based on the Glauber formalism, it was shown that in the multiplicity distribution of pions produced in hA interactions there should be oscillations connected with the contributions of different cut-diagrams to the absorbtive part of the hadron-nucleus amplitude. The magnitude of these oscillations, according to our estimates, should be seen within the statistics of the proposed experiment. Such analysis is impossible in emulsion experiments because of the complex composition of the target which "washes-out" the oscillations.

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† Data on π^-Ne interactions at 200 GeV/c dealt only with the multiplicity of charged particles.[11]

We propose also to study the correlations between the multiplicities of pions and slow ($p \lesssim 1.0$ GeV/c) protons, which is hard to do in electronic experiments. From the study of these correlations, one can obtain very useful information on the interaction of primary particle simultaneously with several nucleons in the nucleus.[16,17]

At the present time there are almost no data on the production of strange particles in hA collisions. Our recent data for π^-Carbon interactions at 40 GeV/c when compared to π^-p data showed[18] that the average multiplicities and inclusive spectra of Λ^o-hyperons and K^o-mesons have little A-dependence (within errors weaker than observed for pions). This result is very surprising and can mean that the contribution of rescattering effects may be even smaller than expected. In the proposed experiment, we want to extend this study by measuring the multiplicity of strange particles in $\pi^{\pm}$Ne and pNe interactions, which while compared to existing $\pi^{\pm}p$ and pp data at 100 GeV/c can provide additional information on the A-dependence of the multiplicity of strange particles.

b) We propose also to measure the inclusive spectra of secondary pions, protons and strange particles in $\pi^{\pm}$Ne and pNe interactions. Once compared to $\pi^{\pm}p$ and pp data, these measurements will give very important information on the A-dependence in different regions of phase space. The special interest is in the detailed study of the region of low and large rapidities. For example, one expects[6-8] that in the region of low rapidities the contribution from cascading is not trivial and can lead to very strong A-dependence. On the other hand, there are some predictions[7,8] that in the region of large rapidities the absolute value of the normalized inclusive cross-section for the nucleus, $(1/\sigma_{in}\, d\sigma/dy)_{hA}$, should be less than that of hydrogen. The evidence for such effects was observed, for example, in our data on π^-Carbon interactions at 40 GeV/c.[9] It is expected that this phenomenon will be more prominent for the heavier Ne nuclei at high energies.

We will also study the inclusive spectra of strange particles (Λ^o-hyperons and K^o-mesons) produced in $\pi^{\pm}$Ne and pNe interactions. The measurements of the momenta of secondaries will also allow for a detailed study of the correlations between particles, which is to some extent a direct check of the short-range phenomena, in the range of large rapidities, as prediced by some models.[5]

c) We propose also to study <u>the inclusive production of protons</u> in $\pi^{\pm}$Ne and pNe interactions. Unfortunately, there are few experimental data on this subject.[10,14] Since the observed protons in hA interactions in most cases are knocked-out protons, the study of their characteristics can give useful information on the contribution of rescattering effects.

On the other hand, at relatively low energies, it was observed[19] that the inclusive spectra of protons produced in hA interactions show scaling-like behavior. Data available at the present time were obtained only up to E_{lab} = 40 GeV.[19] The study of this phenomenon at 100 GeV/c will permit a check of the validity of a "proton scaling" at significantly higher energy.

We are also planning to study the correlations between protons. Recently, in our analysis, we observed[20] a narrow ($\simeq$ 10 MeV) resonance-like peak in the effective mass distribution of two slow protons produced in π^-Carbon interactions from 4 to 40 GeV/c. The observed effect can be explained by final-state interactions. The check of this phenomenon in $\pi^{\pm}$Ne and pNe interactions seems very important to us. The study of the correlations between protons will also be useful from the point of view of the study of the interference effects between like particles.[21]

d) We want also to investigate the inclusive production of ρ-mesons in $\pi^{\pm}Ne$ and pNe collisions. The data obtained from $\pi^{\pm}p$, pp and $\pi^{\pm}d$ interactions[22] showed that a large number (≃ 40-50%) of the observed pions come mainly from decays of ρ-mesons. We expect that at least the same number (if cascading is suppressed in the nucleus) should be observed in interactions of pions and protons with neon nuclei. According to our estimates in the proposed experiment, we would be able to measure the inclusive cross-sections and multiplicities of ρ-mesons produced in $\pi^{\pm}Ne$ and pNe interactions.

e) We should like to note that once obtained in the 15-foot Fermilab bubble chamber these data will also provide very important information on the measurement of the total visible energy (calorimetry) of secondaries recorded in heavy Ne-H_2 mixture. These measurements are important for current and future neutrino experiments with Ne-H_2 mixture at very high energies such as those which will be available with the energy doubler. Moreover, these data will give an opportunity to compare the characteristics of hadrons produced in neutrino (antineutrino)-neon and hadron-neon interactions at high energies.

IV. WHY US?

During the past 8-10 years, our group has been studying the interactions of hadrons with nuclei. We have studied in detail, for example, the interactions of π^- mesons, protons and deuterons with carbon nuclei in propane bubble chambers in the energy range 2-40 GeV/c.[9,10,12,13,20]

We have operating geometrical reconstruction and kinematical fitting programs for bubble chambers filled with heavy mixture. Only minor changes are needed to switch these programs to operate with NeH_2 mixture data. There are 9 measurement devices in our group which are on-line to a computer. This system enables us to measure approximately 250000 tracks per year. In addition, we also have Monte Carlo programs to simulate hadron-nucleus interactions according to the cascade,[23] parton[8] and two-phase[5] models. There are good contacts between our group and the theoretical groups from JINR (Dubna), Landau Institute of Theoretical Physics (Moscow) and the Institute of Nuclear Physics (Leningrad). In the proposed experiment there will be 9 senior physicists and 4 graduate students. This experiment will be the major activity of our group.

V. THE PROPOSED EXPERIMENT

We propose to expose the 15-foot or the 30-inch Fermilab bubble chamber filled with heavy NeH_2 mixture ($\simeq$ 50% neon atomic) to beams of π^- and π^+ mesons and protons at momentum 100 GeV/c. We would expect that with such a composition of neon and hydrogen only $\simeq$ 8% of all recorded events will occur on free hydrogen. Thus, only small corrections are needed to obtain data for a clean sample of interactions on neon. The short radiation length ($X_o \approx$ 60 cm) will give a good detection efficiency for γ-quanta.

For the exposure of the 15-foot Fermilab bubble chamber, we are asking for approximately 7000 pictures per beam ($\simeq$ 21000 in total) (π^-, π^+, and p) with 1-2 beam particles per frame. With this exposure, we would expect approximately 8000 π^-Ne, 8000 π^+Ne and 9000 pNe inelastic interactions with the total number of charged pions: $N^\pi(\pi^-\mathrm{Ne}) \simeq N^\pi(\pi^+\mathrm{Ne}) \simeq N^\pi(\mathrm{pNe}) \simeq 6 \cdot 10^5$. For the exposure of the 30-inch bubble chamber we are asking for ≃ 10000 pictures per beam (≃ 30000 in total) with 4-5 beam particles per frame. This will give us approximately the same number of events as estimated for the 15-foot bubble chamber. The availability of the data on π^-Ne and π^+Ne interactions at the same momentum will give us good information on the spectra of fast protons ($p \gtrsim 800$ MeV/c) which can be obtained using charge symmetry.

The experiment requires about 60 hours, and, for example, for the 15-foot bubble chamber, data can be taken during the calibration exposure for the neutrino experiments.

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